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A general approach to the dynamical-statistical modeling of turbulent flows is developed. The emphasis is on progress in conditional averaging, new scaling, description of intermittency in terms of the inifinitely divisible distributions, high order correlation tensors, modeling of free-surface turbulence and turbulent boundary layers.

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Report on the project

Structure and modeling of free-surface turbulence

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Abstract: A general approach to the dynamical-statistical modeling of turbulent flows is developed. The emphasis is on progress in conditional averaging, new scaling, description of intermittency in terms of the infinitely divisible distributions, high order correlation tensors, modeling of free-surface turbulence and turbulent boundary layers.

Long-term Research Objective: Structure, modeling and control of turbulent flows with high Reynolds number.

S&T Objectives: Dynamical and statistical description of turbulent flows, produced by surface piercing bodies.

Approach: Dynamical-statistical analysis of turbulent flows in terms of vorticity field, deformation rates and intermittency, leading to new schemes for the large-eddy simulations.

S&T Completed: A statistical description of droplets in turbulent spray, connected with the description of turbulent dissipation, is developed. The ideas of similarity, the cascade processes, and the infinitely divisible distributions are used in this description. Formulas for characteristic droplet sizes and corresponding probability distribution are obtained along with a simple formula for turbulent dissipation in flow near a ship [1].

A variational approach to turbulent boundary layers near curved surfaces is developed, leading to an equation for the mean velocity profile. A solution of this equation for turbulent flow along a cylindrical surface is obtained and compared with experimental data [2].

Lagrangian infinitesimal increments of vorticity are considered. The statistical evolution of vorticity increments and fluid elements are studied (particularly, initial tendencies) with various initial orientations of the linear fluid elements relative to the vorticity gradient. The exact results obtained suggest another direction for numerical experiments in turbulence [3].

High order correlation tensors for vorticity and deformation rates are obtained [4]. Particularly, a surprising connection is found between correlation of deformation rates and the turbulence scaling, including the effect of intermittency [4-6].

Impact / Navy Relevance: The obtained results revealed new aspects of turbulence scaling and intermittency, which can be incorporated in the general dynamical-statistical modeling of well developed turbulent flows [6].

Planned Research Efforts: We plan to generalize our previous results on conditional averaging of vorticity field, description of intermittency effects in terms of the infinitely divisible distribution and new scaling of turbulence (which now have strong experimental support) to provide a basis for a statistical enslavement of the small-scale turbulence. In combination with the variational approach to turbulent boundary layers near curved solid surfaces, which we recently developed, this will lead to a capability of simulation of turbulent flows with high Reynolds number, which are produced, particularly, by surface piercing bodies and by submersibles.

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